NAVAL POSTGRADUATE SCHOOL
Monterey, California

THESIS

THE U.S. GOVERNMENT ROLE IN FOREIGN
TRADE -- WHAT IS THE BEST APPROACH?
A CASE STUDY OF THE
U.S. SEMICONDUCTOR INDUSTRY

by

Jeffrey D. Carpenter

March 1990

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This thesis examines the current state of the U.S. semiconductor industry in light of its alleged decline relative to foreign producers, specifically Japan, in the hope that an appropriate federal policy might be identified, based on current market conditions. Justification for federal intervention into private sector industry and the appropriate federal intervention methods are included, leading to a discussion of the national security benefits derived from a strong domestic semiconductor industry. Various micro federal government intervention methods are analyzed including a hands off policy, tariffs, anti-dumping measures, strategic stockpiling, DOD production, a Buy American policy, subsidized domestic production, and industry consortia. The goal is to determine how effective they will be in bolstering the U.S. semiconductor industry. However, the problems in the semiconductor industry are seen more as macro problems affecting the economy as a whole. Thus, the recommended intervention policies focus more on macro solutions including changes to the tax structure to encourage savings and discourage debt in order to reduce the cost of capital in the U.S. These solutions will tend to stimulate the economy as a whole, rather than stimulating the semiconductor industry by itself.

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The U.S. Government's Role in Foreign Trade--
What is the Best Approach?
A Case Study of the U.S. Semiconductor Industry

by

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ABSTRACT

This thesis examines the current state of the U.S. semiconductor industry in light of its alleged decline relative to foreign producers, specifically Japan, in the hope that an appropriate federal policy might be identified, based on current market conditions. Justification for federal intervention into private sector industry and the appropriate federal intervention methods are included, leading to a discussion of the national security benefits derived from a strong domestic semiconductor industry. Various micro federal government intervention methods are analyzed including a hands off policy, tariffs, anti-dumping measures, strategic stockpiling, DOD production, a Buy American policy, subsidized domestic production, and industry consortia. The goal is to determine how effective they will be in bolstering the U.S. semiconductor industry. However, the problems in the semiconductor industry are seen more as macro problems affecting the economy as a whole. Thus, the recommended intervention policies focus more on macro solutions including changes to the tax structure to encourage savings and discourage debt in order to reduce the cost of capital in the U.S. These solutions will tend to stimulate the economy as a whole, rather than stimulating the semiconductor industry by itself.

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I. INTRODUCTION

A. BACKGROUND

According to various high level government and industry experts, the U.S. semiconductor industry today is at risk of losing its technological superiority in the global market. Microchips, which are comprised of integrated circuits containing thousands of electrical components, are now the key components for computers, telephones, and other consumer electronic products. The U.S. semiconductor industry accounted for $250 billion of the nation's industrial output in 1986, a full 15% of the total. [Ref. 1:p. 89] In addition to the commercial aspects of semiconductors, they have become vital to maintaining the U.S. technology lead in weapons systems and other important military applications. Many discussions concerning government policies toward the semiconductor industry give the perception that the defense program, the economy, and the entire industrial base of the U.S are at risk because all depend on electronic technology leverage which today is driven by semiconductor technology. [Ref. 2:p. 11]

There are also those who feel that the entire issue is overstated and exaggerated. They feel that although the U.S. does not still possess the same share of the global market as it did immediately following World War II, the U.S. economy is strong and still has about the same share of the world market as it did in the mid-1960s.

For those who feel that federal intervention in the private sector is justified in the case of the semiconductor industry, there are many conflicting schools of thought regarding the appropriate response. On one hand, there are those who maintain that free international trade will reach its equilibrium point if left alone. They feel that as international trade is allowed to occur freely, nations will produce goods and services which benefit each according to their comparative advantage. [Ref. 3:p. 27] This approach tends to have a long-term perspective towards solving the problem.

On the other hand, there are others who maintain that the semiconductor industry is too important to the U.S. economy and national security to take a laissez-faire approach. From the government's and the semiconductor industry's perspective, judging from the Defense Science Board Task Force Report On Defense Semiconductor Dependency (comprised of high ranking government officials and representatives of the merchant semiconductor industry), the time to act is now. They tend to take a more short-term approach to solving the problem.

B. OBJECTIVES AND RESEARCH QUESTIONS

The objective of this thesis is to examine the U.S. semiconductor industry to determine if sufficient market imperfections exist to justify the intervention of the federal government in this private sector market and if so, to examine the appropriate policy responses open to the federal government. In order to direct this study, the research questions to be addressed include:

- What is the proper justification for government intervention in private sector business?
- What methods of intervention should be used to for different market imperfections?

- Is there sufficient justification for the federal government to intervene in the U.S. semiconductor industry?
- If so, what are the appropriate responses?
- How successful has federal intervention been in the past?
- How important are semiconductor chips to our national security?
- What options are open for the federal government to solve the problem?
- How does a long-term approach differ from a short-term approach to solve the problem?

C. SCOPE AND LIMITATIONS

This thesis is a case study of the semiconductor industry focusing on the appropriate role for the federal government to play, if government intervention is justified. The Dynamic Random Access Memory (DRAM) microchip sector of the semiconductor industry's market will be emphasized, since that is the one sector where the U.S. has lost its market share to overseas competitors over the last several years. While several competitors have taken part in the overseas shift for DRAM market share, by far the most dominant competitors are Japanese. For that reason, the Japanese semiconductor industry and business environment will be emphasized in this thesis.

D. ORGANIZATION OF STUDY

The remainder of this thesis address the research questions stated above. Chapter Two will include a general discussion of justification for intervention into private sector business, a general discussion of appropriate economic responses when justification is substantiated, a brief history of the semiconductor industry, and a discussion of past federal intervention into the semiconductor industry. Chapter Three will include a discussion of the national security issue that has been tied to a domestic production capability for the U.S. Chapter Four will include a discussion of a number of micro options available to the federal government to specifically bolster the U.S. semiconductor industry. Chapter Five will include a brief look at possible macro solutions, conclusions, and recommendations for further research and study.

II. FEDERAL GOVERNMENT INVOLVEMENT IN THE U.S. SEMICONDUCTOR INDUSTRY

A. APPROPRIATE FEDERAL ROLE FOR SEMICONDUCTOR TECHNOLOGY DEVELOPMENT

Before determining which type or types of federal incentives would be most appropriate for the semiconductor industry in the U.S., the issue of what justification is sufficient for federal participation in the R&D process for semiconductors must be addressed. Once federal intervention is justified, the appropriate method of intervention must be matched to the rationale justifying federal intervention to most efficiently and least expensively correct the situation.

1. Justification for Federal Intervention

Federal Research and Development (R&D) funds historically have targeted projects dealing with technology development for public sector use or basic research, such as problems studied by the National Science Foundation. In more recent years, however, increasing levels of federal support have been directed towards the private sector and commercial applications.

One justification frequently offered for federal support for R&D in the semiconductor industry is the extremely high capital investment required to develop new generations of microchips and manufacturing techniques. This does not necessarily indicate that federal support is justified in the semiconductor industry. A lack of interest from private sources for capital investment may merely indicate that insufficient profit potential exists in the latest semiconductor industry R&D. A firm will tend to invest in a given R&D project if its estimated returns exceed the risks for the R&D required. The private sector has demonstrated the ability to fund R&D projects if the returns are sufficient. If the risks exceed the estimated returns, private firms will tend not to invest. [Ref. 4:p. 16]

One justification for federal participation in commercial R&D would be if the social rate of return exceeds the social risks. Social returns benefit the public as a whole, such as highway systems, whereas private returns benefit only those making the investment. If the private and social returns or private and social risks diverge and the social returns are high enough to bear the social risks, then federal government participation is justified. This divergence between social and private R&D returns and risks is caused by market imperfections. The first step in choosing areas to target with federal incentives is to identify the relevant market imperfections. Then the significance of the imperfections should be determined by comparing the expected social costs and returns of R&D. Since the federal budget is limited, alternate R&D projects should be compared against each other to determine the optimum area for federal participation. [Ref. 4:p. 17]

Market imperfections or failures can be organized into four general groups:

- Appropriability
- Uncertainty
- Indivisibility
- Indirect failures [Ref. 5:p. 3]

Appropriability imperfections arise when private firms are unable to take advantage of the benefits resulting from their technology development projects. It can be difficult for a firm to appropriate the benefits of its R&D if imitation is easy or if the research results can be used by other firms in the industry or other industries. In such cases, firms will under invest in R&D because they incur all the costs, but only receive a portion of the benefits.

One reason frequently given to justify federal participation in basic R&D is that the benefits of R&D are often particularly hard to appropriate. It is also extremely difficult to appropriate external benefits, such as increases in national security due to reductions in semiconductor imports, because market prices do not fully reflect external benefits.

When technology is easily imitated, appropriability is frequently a problem. The U.S. patent system was developed originally to maintain appropriability. Today, however, U.S. and foreign researchers can engineer very close to the originator's design without violating patent laws, while not investing the full value for the information. Overseas enforcement of U.S. patent laws is still very difficult. The lower cost of development for imitating firms reduces the costs they must recoup relative to the original developers of the product. This reduces the incentive to develop new technology. The optimum degree of appropriability is hard to find, however, since perfect appropriability would ensure a monopoly for the innovator. [Ref. 4:pp. 18-9]

The potential bias against capital intensive, high risk R&D projects associated with private R&D funding decisions is referred to as uncertainty. Uncertainties inherent to R&D, private industry's aversion to risk, and the absence of R&D insurance, each contribute to this bias. Smaller R&D projects and projects with multiple approaches are favored over projects which are large and contain radically new products because this diversification tends to reduce the effects of uncertainty.

Indivisibilities arise in larger projects where economies of scale exist. Indivisibilities arise where it is impossible or prohibitively expensive to divide a large R&D project into smaller tasks that can be funded by smaller individual firms. With this imperfection, small firms are excluded from larger capital investments like R&D for next generation semiconductor chips. Since R&D projects with economies of scale can only be supported by large firms or a consortia of smaller firms, indivisibilities often limit private investment. If there is an expectation of profit with a low enough risk as a result of R&D, however, industry in the U.S. has displayed its ability to raise the requisite venture capital. In cases like these, federal participation in funding R&D should probably be used only in areas where private industry is incapable of supporting the most suitable R&D approach.

Private market interventions and other federal policies that influence private semiconductor industry R&D decisions indirectly, can result in indirect failures. Indirect failures are often vague and complicated because of the domino effect with economic failures. The semiconductor industry exhibits many indirect failures which often have conflicting impacts. For example, tax structures, antitrust policies, and patent laws are sources of indirect failures. Indirect failures are relatively poorly defined and often have neutralizing effects upon each other. [Ref. 6:p. 30]

When market imperfections justify federal intervention in R&D beyond the basic stage, intervention must be used cautiously for two reasons. First, it is difficult to determine the impact the numerous direct and indirect imperfections have on private R&D investment decisions. Second, since market imperfections can be found in almost all industries and R&D projects, and federal intervention involves appropriating scarce federal resources, federal participation should be limited to those sectors which have the most severe problems. Regardless of which sectors need the help the most, justification for federal participation in a particular private sector R&D project is indicated only if the expected social return is greater than the return from competing R&D projects and from federal fund's alternative uses. [Ref. 4:pp. 22-4]

2. Appropriate Policies

Once justification for federal intervention is substantiated, the next question to address is which federal intervention methods provide the appropriate incentives at the lowest social cost? Costs of each incentive method deemed appropriate should also be considered because of the importance of prudently appropriating scarce federal funds.

Various federal policies which exist to stimulate industry R&D include direct R&D funding, federal research grants or prizes, federal procurement policies, input and output subsidies, tax incentives, patent policy, and government performed R&D.

Traditionally, federal policy makers have favored direct control over basic and public sector R&D. Unfortunately, direct funding of R&D only attempts to treat the symptom of inadequate private sector funding, rather than correcting the root problem caused by the market imperfection involved. Furthermore, this tactic tends to be rather inefficient. Private sector R&D is guided by competitive market forces. Federal policy makers, however, tend to respond to political pressures. These responses, consequently, may not be appropriate even if the correct market information is received. [Ref. 6:p. 31]

It is unrealistic to think that a general micro policy for federal intervention in commercial R&D would optimize all firms' investments, because each firm's environment is quite different. Application of federal incentives need to be considered on a case by case basis, while considering such factors as the private market environment, market imperfections present, and the potential side effects of the various interventions employed. Federal funding of R&D projects tends to be effective where the public sector is the consumer and the procurement policies associated with the products alone are not effective at fostering R&D. As R&D projects move closer to commercial application, private market forces increase in importance and market failures increase in variety. Such is the case with the semiconductor industry in the United States.

One mechanism that can be used to counter most market failures is the use of grants and prizes to encourage research in specific areas where research is not being done. Commercial and scientific integrity for this technique are preserved by employing potential users and scientists when awarding prizes and grants. This mechanism tends to avoid many of the pitfalls associated with federal control of R&D. [Ref. 4:pp. 43-4]

The U.S. patent system, designed to prevent appropriability problems, might be improved to encourage R&D in certain areas. The advantages of this type of market intervention is that private market incentives are preserved and the private sector maintains control of the process. However, drawbacks include the relative ease with which competitors imitate or invent around patents, especially in the semiconductor industry, and the monopoly power which is granted to an innovating firm if its patent is effective.

Federal procurement is one mechanism to employ when significant market uncertainties exist or when external benefits are generated by early use of technology which limit private R&D investment. At least initially, a federally guaranteed market may provide enough incentive to stimulate sufficient private R&D investment. Unfortunately, the federal government does not represent a significant market for the U.S. semiconductor industry today, as it did at the advent of the semiconductor. [Ref. 4:p. 45]

In cases where deviations exist between actual prices and socially optimal prices which negatively affect R&D investment, input or output subsidies are often recommended. Private industry will tend to undervalue and hence, under invest in new technologies which generate significant external benefits. In the commercial semiconductor industry, new technology generates significant external benefits, such as increased military technological superiority which contributes to enhanced national security.

The most popular input subsidy methods are accelerated depreciation, tax credits, and loan guarantees. However, these mechanisms all distort a firm's choice of capital and labor by subsidizing the cost of capital. For example, loan guarantees encourage high debt ratios by transferring risk to the federal government from the private sector, thus encouraging high interest rates.

On the other hand, output subsidies, including price guarantees, are not tied to factors of production and do not distort private market decisions.

Output subsidies are preferred over input subsidies by most economists because they correct deviations in actual prices while maintaining incentives for private production and cost minimization. When market imperfections call for subsidies as the method of intervention, input subsidies should only be used when output subsidies are impractical or infeasible because of the market advantages inherent to output subsidies. Input subsidies give federal bureaucrats more influence over the private sector especially when the industry is considered important. Furthermore, because input subsidies obscure the costs to the government, they are preferred by both the public and private sectors.

3. Summary

When choosing the appropriate policy to stimulate R&D in a particular area, the stage of the R&D process, the market failures present, and the industry's market environment should all be considered. [Ref. 4:pp. 47-9]

If federal intervention is to be used in a particular industry or sector, the policies should be selected on a case by case basis. Particular attention should be focused on the market failures, the R&D stage, the capacity for centralized R&D control, the role of private market incentives, and the environment of the associated industry's market. [Ref. 4:p. 51]

It would appear that the semiconductor industry in the U.S. is affected to some degree by the market imperfections of appropriability and uncertainty. First, the market place itself does not consider external public benefits, such as increased military technological superiority, which contribute to enhanced national security. Federal subsidies would appear to be an appropriate intervention to address this appropriability imperfection and encourage private semiconductor firms to invest in advanced R&D projects.

Second, the market imperfection of uncertainty which discourages capital investment in the semiconductor industry could be addressed through a federal procurement policy to reduce the uncertainties associated with capital intensive R&D.

B. HISTORY OF THE SEMICONDUCTOR INDUSTRY

Initiating the development of the transistor and then the semiconductor, the modern electronics industry began in the U.S. The semiconductor industry thrived initially because innovative talent required for its success was in abundant supply. Numerous startup companies with an entrepreneurial spirit made tremendous strides in a very short time due to inherent competition and the semiconductor's capacity for technological innovation.

A major portion of the microchip market today is involved in the manufacturing of dynamic random access memory (DRAM) chips. DRAMs (pronounced dee-rams) are used for immediate data storage in every computer. In 1975, U.S. companies controlled 90 percent of the world market for DRAMs. In 1986, that share had shrunk to 5 percent as Japan, other Pacific Rim countries, and even the Europeans took over the market. [Ref. 7: p. 47] Because the DRAM market accounted for only about 15% of the total microchip market, the impact of this loss of market share was lessened. Furthermore, this data only includes merchant DRAM producers (companies producing DRAMs for sale on the open market). If captive producers (firms producing DRAMs for internal consumption only), such as IBM and AT&T,

are included, the U.S. share of DRAM production would increase significantly.

1. Strong Federal Support

Like the aircraft industry in its early days, the semiconductor industry sold mostly to a government related market. It benefited from the support of research sponsored by agencies ranging from the National Science Foundation (NSF) to the Department of Defense (DOD). The industry also enjoyed strong federal support given during the 1960s to advance scientific and engineering education. [Ref. 8:p. 6] Today, only three percent of the U.S. semiconductor industry's output is purchased by the DOD. This reduction of market demand from the DOD has also reduced its leverage in affecting the semiconductor market.

Most recently, the U.S. semiconductor industry has resorted to the national security issue for protection against Japanese chip makers. This tact has been successful because most policy makers agree that a strong domestic semiconductor industry is necessary for U.S. national security interests. [Ref. 8:p. 6] These same policy makers, however, have been responsible for other policies in the past which have had adverse results for the U.S. economy.

2. Semiconductor Pact of 1986 and SEMATECH

The electronics industry's importance for the U.S. economy has allowed it to appeal to the government for help in dealing with foreign competitors. This resulted in the 1986 semiconductor pact with Japan and the establishment of the Semiconductor Manufacturing Technology (SEMATECH) consortium in 1987. [Ref. 7:p. 47]

In 1986, after being accused by the U.S. semiconductor industry of dumping its DRAM chips (i.e., selling them for less than cost in foreign markets or employing price discrimination between domestic and foreign markets), Japan agreed to refrain from selling its chips to overseas markets for less than the market price. Although the semiconductor industry received exactly what it requested, the pact resulted in more advantages for the Japanese. In the years immediately preceding the pact, Japanese chip makers lost some $4 billion as they over expanded DRAM production and sold their excess chips in the U.S. The pact required the Japanese to limit their DRAM sales in the U.S., which raised the price of these chips significantly. After the pact, Japanese manufacturers made huge profits and funded big R&D programs designed to close the U.S. lead in state-of-the-art microchips and design tools. By limiting imports, the U.S. actually encouraged the Japanese to sell fewer semiconductor chips at higher profit margins, which resulted in greater profits for the Japanese. Despite the protection provided by this pact, U.S. producers failed to significantly increase DRAM output.

After the 1986 semiconductor pact failed to re-establish the U.S. DRAM industry, the semiconductor industry appealed to the U.S. government for further assistance. In 1987, the Department of Defense (DOD) commissioned the Defense Science Board Task Force on Defense Semiconductor Dependency to address perceived semiconductor industry problems which could potentially have a detrimental affect on the national security of the United States. The board focused primarily on solving potential national security problems caused by the apparent decline of the semiconductor industry relative to overseas competition, specifically from

Japan. [Ref. 9:p. 7] According to a Japanese publication, their recommendations focused on "improving mass production capabilities--an area that the U.S. has been deficient in and has tended to neglect." [Ref. 10:p. 1066] The main recommendation from the task force was to form a government backed semiconductor manufacturing consortium called *Se*miconductor *Ma*nufacturing *Tech*nology Institute or SEMATECH.

3. Differing Views

There are, however, other views which differ from those of the outspoken semiconductor insiders. Some feel that the U.S. semiconductor industry is not really as bad off as the industry spokespersons would like us to believe. The U.S. global lead in computer hardware is shrinking slightly, but remains relatively large. Total electronic systems production by U.S. firms in 1987 was some $143 billion, two-thirds larger than Japan's. Indications are that the U.S. global share in hardware technologies has not fallen significantly since 1982. This is a considerable accomplishment considering the ferocious competition, especially in DRAM manufacturing. [Ref. 11:p. 81] Finally, in the DRAM market, sales data exclude production by captive producers like IBM and AT&T. This probably understates the U.S. share of the market by a significant margin.

Is the U.S. semiconductor industry in dire straits? The answer given generally depends on the viewpoint of the respondent. Typically, large, established semiconductor firms present a pessimistic prognosis. For example, the Defense Science Board Task Force concluded that the industry is in deep trouble. But most members of the task force tended to represent parochial interests of established semiconductor firms. Their consensus was that direct government involvement was necessary to save the semiconductor industry. On the other hand, leaders of small innovative semiconductor firms, which exploit new technologies, are more optimistic about the industry's future and less likely to support government intervention. One view holds that "the U.S. semiconductor industry has historically responded to intense competition among domestic companies as well as with Japanese and European firms--by a producing a continuous stream of new devices, reducing production costs, and expanding applications, creating new and larger markets." [Ref. 12:p. 13]

In the past few years, "small Silicon Valley Start-ups . . . have . . . focused on producing limited numbers of sophisticated, custom-made chips. The trend is toward smaller and smaller chips with more and more room to store information on each one . . . . The value of chip design is increasing exponentially." [Ref. 13:p. 10]

Those who advocate free trade for the industry make statements like, "the 99 U.S. semiconductor startups launched over the last five years--from Cypress to Actel--constitute the fastest-growing new generation of merchant semiconductor firms in the history of the industry. So much for the U.S. chip industry's needing protection." [Ref. 11:p. 82]

Those same proponents of free trade say that Japan's lead over the United States is only in the production of the most basic kind of memory chips, DRAMs. Although once thought to be critical to manufacturing technologies, heavy production of DRAMs is not universally thought to be as critical anymore. [Ref. 13:p.10] There is much debate over that point, however, as some believe that preeminence in the semiconductor industry must include preeminence in DRAM manufacturing technology. Others believe that DRAM production has moved to the low-tech end of the semiconductor industry while the U.S. remains the leader in high-tech, innovative, customized microchips.

4. Alleged Causes of U.S. Decline

Proponents of government support cite at least three reasons for the apparent decline of the U.S. semiconductor industry: advantages of the Japanese approach, imitation, and the Japanese corporate structure.

The Japanese have taken a very different approach than that taken in the U.S. in recent history. For example, the Japanese favor larger firms with a more vertically integrated structure for its semiconductor industry, while U.S. firms tend to be smaller and more specialized. This allegedly enables Japanese firms to better afford to pursue R&D projects with longer lead times, sometimes up to ten years. [Ref. 3:p. 31]

The predominantly vertically integrated internal structure of their companies has favored Japan over the last decade. Japanese chip makers design and fabricate massive quantities of chips for their affiliates to incorporate in finished products as well as for export. (Of course, under different circumstances, vertical integration can be a disadvantage.) Except for IBM and AT&T, which are prohibited by anti-trust laws from entering the merchant semiconductor market, "the U.S. industry is fragmented into high-volume merchant companies that sell chips to other manufacturers, a few Japanese-style vertically integrated companies (like NCR), semi-custom manufacturers (like LSI Logic Corp. and VLSI Technology, Inc.), and design or process specialists (like Brooktree Corp.)." [Ref. 7:p. 49]

The cost of investment capital has also been lower in Japan, relative to its cost in the U.S., during the early and mid 1980s. Because of this, Japanese investors can accept a much lower and slower return on their capital investment than can U.S. firms, who must achieve short-term profitability to survive. [Ref. 7:p. 49]

While licensing of U.S. semiconductor products is practiced, a significant amount of illegal imitation is also practiced, enabling imitators to capture market share very inexpensively. For instance:

> Imitators are a problem with the semiconductor industry since they capture large parts or the bulk of the market. For evolutionary devices like the first 64K DRAM, which incrementally improved upon 16K DRAMs, the market share was lost by the innovator of a new device in roughly two thirds of the cases. [Ref. 3:p. 31]

Because these reasons for the decline in the domestic semiconductor industry, along with appeals to national security, are used to justify federal intervention in the U.S., it is important to consider them carefully.

C. FEDERAL PARTICIPATION IN BOLSTERING THE DEFENSE INDUSTRIAL BASE

The success enjoyed by the industrial base of the U.S. has been due largely to the fundamental characteristics of the economic system, rather than through the participation of the federal government. Rather than promoting the health of American industry, the federal government historically has focused on protecting consumers against business excesses. U.S. industrial success occurred, despite the federal government's involvement, because the economic system in place provided the means for creating wealth through the freedom to reap profits from hard work and innovation, allowing the U.S. to become the leader in world output and technology. In the past, U.S.

industry has not needed government support to flourish, although the federal government did play a vital role in funding R&D for numerous government and defense related projects.

> In the 1950s and 1960s, American industry dominated world manufacturing. American manufacturers could focus on quantity to the neglect of quality. American manufacturers were complacent, while other countries began building powerful new industrial infrastructures and developing superior process technology to manufacture easily-obtained American product designs and technology. [Ref. 14:pp. 14-5]

The lack of a focal point in the federal government to consider the impact of potentially conflicting policies relating to the "industrial base often causes inadvertent but harmful results." [Ref. 14:p. 16] In recent years, certain federal government policies designed to aid an industry, such as the Semiconductor Pact of 1986 with Japan, have actually reduced the overall competitiveness of the U.S. industrial base because of conflicting effects on industries related to and dependent on semiconductors.

Some people perceive that import barriers erected by foreign governments have created an unlevel playing field that favors foreign business. However, in recent years, U.S. domestic policies and practices have also contributed to that perception. The growing national deficit contributes to the high cost of capital in the U.S. Tax laws which reward personal credit and discourage personal savings all contribute to a higher cost of capital in the U.S. Examples include: home mortgage deductions, double taxation of interest and dividend income, reduction of tax benefits for individual retirement accounts (IRAs), and unfavorable capital gains taxes.

Intrusions into the market by the legislative and the executive branches of the U.S. government, including the tax code, anti-trust laws, and DOD acquisition policies often discourage capital investment in domestic industry. While these restrictive laws may have been appropriate and effective in years past, some changes may need to occur to reflect significant foreign competition. [Ref. 14:p. 16]

Historically, the semiconductor industry in the U.S. has had a strong interest in military and space applications. While most of the early work that laid the foundations for the semiconductor industry was privately financed, a governmental market, rather than a private market, made it profitable for firms such as Texas Instruments and IBM to invest in semiconductor and computer R&D. [Ref. 8:p. 456] Advanced education and university-based research relevant to these industries have continued to receive public financial support. [Ref. 8:p. 452] DOD, who was once the largest semiconductor consumer, now accounts for a very small portion of the semiconductor market by volume or by sales revenue. [Ref. 7:p. 48]

Under DOD, the Defense Advanced Research Projects Agency (DARPA) "has had an impact on the nation's technology development well out of proportion to its size. With projects like high-definition television and SEMATECH, DARPA is being propelled, only partly by its own choosing, into the role of venture capitalist for America's high-technology industry." [Ref. 16:p. 1, sec. 3]

As a result of perceived microchip dumping, the semiconductor industry sought and obtained governmental action in the form of anti-dumping sanctions against Japanese chip makers in 1986. The effects of this anti-dumping campaign turned out to be disastrous for most U.S. consumers of DRAM microchips. Spot shortages and increased prices made a significant detrimental impact on many U.S. domestic consumers (e.g., the computer industry) who had come to rely on an inexpensive and sufficient source of DRAMs.

In 1987, the U.S. government began financial support of SEMATECH to expand the research and development (R&D) of advanced manufacturing techniques. The objective is to catch the Japanese who have surpassed the U.S. in terms of DRAM manufacturing capabilities.

The most recent government attempts to support the DRAM industry may be counterproductive. Considering the domination the Japanese have achieved in the DRAM market, and the results of the 1986 Semiconductor pact, there is reason to question further efforts to protect this industry in the U.S.

One positive feature of the government's commitment to SEMATECH is that its continued funding depends on an annual affirmation by the President to ensure the government/industry consortium is succeeding in its goal to improve DRAM manufacturing competitiveness. This policy will help minimize the government's losses, if SEMATECH does not succeed. Historically, the federal government has been slow to kill ongoing projects in the face of pessimistic prognoses (i.e., SST, nuclear breeder reactor). [Ref. 7:p. 50]

III. NATIONAL SECURITY AND THE SEMICONDUCTOR INDUSTRY

In this chapter, the views of those who favor actions to protect and promote the U.S. semiconductor industry in the interest of national security are stated predominantly. This reflects the fact that federal policy makers appear to have adopted this position. The views of those who favor more free market economics are included at the conclusion of this chapter.

A. WHAT IS NATIONAL SECURITY?

The concept of national security has taken on an overwhelmingly military flavor since World War II. The military threat to national security, however, is only one of many which include political, economic, social, and environmental threats. [Ref. 17:pp. 21-3] Military power is useless against these new threats. Nonmilitary threats to a nation's security are not as clearly defined as military ones. According to Lester Brown, the goal of national security policy should be to maximize national security rather than to just maximize military power. [Ref. 17:p. 22]

To some, the shrinking of America's share of world production is alarming because of its implications for American grand strategy, measured not by military forces alone, but by their integration with all those other elements which contribute toward a successful long-term policy. [Ref. 18:p. 29]

In 1965, Berkowitz and Bock defined national security by stating, "[it] can be most fruitfully defined as the ability of a nation to protect its internal values from external threats." [Ref. 19:p. x] In 1968, Robert McNamara discussed the trend to militarize the term when he wrote that "we have been lost in a semantic jungle for too long and have come to identify security with exclusively military phenomena and most particularly with military hardware. It just isn't so." [Ref. 20:p. 150] Writing in *American Defense Policy,* Reichart and Sturm state:

> Security concerns not only the protection of "values previously acquired," but also expectations about the future and the value outcomes to be experienced at a later time. Thus, security concerns not only the avoidance of loss, but also the prevention of blocked gain. . . .
>
> Security can now be defined more formally as the expectation of retaining and enhancing the ability to partake of highly regarded value outcomes free of obstructions. National security thus becomes security with respect to 'value outcomes' desired by those who comprise the effective political base of a nation. [Ref. 21:p. 19]
>
> National security cannot be maintained unless national economies can be sustained, but, unfortunately, the health of many economies cannot be sustained for much longer without major adjustments. National security requires a stable economy with assured supplies of materials for industry. In this sense, frugality and conservation of materials are essential to our national security. Security means more than safety from hostile attack; it includes the preservation of a system of civilization. [Ref. 21:pp. 22-4]

Thus, national security involves military and economic issues. Many feel that maintaining a domestic production capability for the most advanced semiconductor products is necessary, from both a military and economic view point, for the U.S. to maintain its national security. There is an opportunity cost associated with that domestic capability, however, because the cost of R&D required for advanced electronics is high. If the U.S. would import its semiconductor supplies, rather than producing its own, the costs would most certainly be reduced, at least for the short term. These resources could be used for other military or domestic purposes. Thus, national security concerns should be considered carefully.

B. THE MILITARY THREAT

Amidst these times of radical change in world politics, the most significant military threat to U.S. national security continues to come from the Soviet Union. The Soviets continue to build their arsenal of nuclear and conventional weapons despite major concessions to numerous political groups inside and outside the Soviet Union. They have attained an undisputed numerical superiority of weapons systems over all of their potential adversaries, including the U.S. Historically, the Soviets' arsenal was built with technology significantly inferior to that of the U.S. and of the West. Since the Soviet's began their military buildup, and especially since the Soviets surpassed the United States in weapons quantity, the U.S. strategy of employing technologically superior weapons systems has attempted to counter the numerically superior Soviet forces. In recent years, the Soviets have also recognized that:

> Progress in many key areas of warfighting capability will require advanced microelectronic and computer technology. Consequently, the Soviets have made acquiring this technology a high priority. As the US lead in semiconductor technology is reduced by formidable competition from Japan, the Soviets are increasing their technology acquisition efforts in Japanese laboratories and industries. [Ref. 22:p. 135]

As the Soviets seek to close the technology gap with the West, "sophisticated defense systems produced by advanced technology sectors of a nation's industrial base will prove even more important to Western defense in the future." [Ref. 22:p. 139]

> The new argument runs like this: Leadership in semiconductor technology is a "force multiplier." That is, high-technology U.S. weapons offset whatever quantitative advantages the Soviets possess. Semiconductor applications enhance U.S. military capabilities

particularly in early warning, air-defense, and air-to-surface-attack systems; conventional artillery and tanks; and naval surface warfare. [Ref. 7:p. 47]

In addition to enhancing the performance of various weapons systems, semiconductor chips are also used to increase their efficiency through sophisticated intelligence and command and control systems.

Increasingly over the past years, the U.S. has come to rely on this force multiplier when developing and purchasing new and improved weapons systems. Because the U.S. is placing so much of its reliance on superior technology in semiconductor and electronics applications for its defense posture, many feel that it is extremely important that the U.S. maintain its leading edge technology. [Ref. 9:p. 17] If that edge is lost and made available to U.S. adversaries, specifically to the Soviet Union, the balance of military power would shift totally in the Soviets' favor, since they would then have the quantitative as well as the qualitative advantage. Closely tied with the fate of the U.S. in this situation is that of the nations of the North Atlantic Treaty Organization (NATO) whose forces similarly rely on a technological advantage. This advantage is ultimately traceable to semiconductors. [Ref. 15:p. 6] Thus, national security requires the ability to exploit new semiconductor technology for military purpose.

A related national security issue concerns potential cutoffs from foreign suppliers. For example, some hold the position that "our national defense is not dependent now upon foreign manufacturers and must not become dependent in the future." [Ref. 9:p. 21] They warn that "the chief economic danger in a limited war is one . . . [where] . . . a cutoff in vital materials [is] supplied by enemy-sympathizing foreign powers on which we had become dependent." [Ref. 23:p. 150] For instance, if the U.S. were to become almost totally dependent on Japan for its supply of chips for weapons systems, and if its supply were interrupted due to Japan restricting access or making these chips available to the Soviet Union, the balance of power could change drastically. [Ref. 15:p. 14] The bottom line here is that the U.S. would not have another country to really depend on to insure that it had continued access to the most advanced technology in semiconductors available. [Ref. 9:p. 22]

The recent trend, however, indicates a shifting of DRAM manufacturing technology and production to other Pacific Rim nations such as South Korea, Taiwan, Singapore, etc. Furthermore, Japan is dependent on the U.S., maybe even to a greater degree than the U.S. depends on Japan. This reduces Japan's ability to cut off supplies of critical defense products.

DOD needs then to maintain a secure supply of sophisticated electronics and the capability to design new systems that exploit these technologies. Some analysts believe that this requires a domestic semiconductor industry to continue to supply state-of-the-art electronics for its weapons systems. [Ref. 3:p. 29]

For example, in February 1987, the Defense Science Board Task Force on Semiconductor Dependency concluded that:

- U.S. military forces depend heavily on technological superiority to win.
- Electronics is the technology that can be most highly leveraged.
- Semiconductors are the key to leadership in electronics.
- Competitive, high-volume production is the key to leadership in semiconductors.
- High-volume production is only supported by the commercial market. [Ref. 24:p. 94]

While a domestic production capability for advanced semiconductor manufacturing is the direction the Defense Science Board recommended, it is an option with very high costs. Since, the Japanese have a solid lead in the production of DRAMs, the costs involved with re-acquiring the lead in DRAM production may be prohibitive, or the money more effectively invested elsewhere, and offer very small rewards over other alternatives such as diversified foreign supply.

The decision to protect the domestic semiconductor industry on the basis of national security should be based on the costs and benefits of this proposal. The benefit is determined by the severity of the national security threat. This depends on both the extent of our foreign dependence on semiconductors and the possibility of a supply cutoff, as determined by the nature and duration of potential future conflicts.

1. Dependence on Foreign Suppliers of Semiconductors

The United States today is dependent on Japan for a significant number of components used in several critical weapons systems which would be essential for prosecuting any prolonged conflict. [Ref. 22:p. 138] According to Dr. Kerber, testifying before the 1987 DSB Task Force on Defense Semiconductor Dependency,

> . . . a number of systems were found to contain semiconductors available only from foreign-owned, foreign-located, sources. GPS, IUS, DCSC, DSP, DMSP, FLTSATCOM, ASAT, ASN-10, F-16, AIM-7, SSQ AN-53B, AN/APG-63, HP, M1 Tank, AHIP, AN/ARC-182, AN/PRC-119, AN/ASN-92, AN/AYK-14, AM-6988 A POET, F-18. Many domestic semiconductors used in military systems are packaged and tested in foreign countries and ceramic packages are available almost exclusively from Japan. [Ref. 9:pp.21-2]

While Dr. Kerber testified about the number of weapons systems which have components produced in foreign countries, National Defense University studies reveal that "U.S. dependence on foreign suppliers varies greatly from one weapon system to the next, making generalizations difficult." [Ref. 25:p. 9] In fact, until recently, DOD was not keeping accurate records on the place of manufacture of components used in its weapons systems.

The DSB task force concluded in 1987 that although U.S. dependency is modest today, trends in semiconductor manufacturing indicate that the U.S. will become increasingly dependent on foreign sources if preventative actions are not taken. [Ref. 9:p. 5] Under current trends, the task force expected the U.S. to reach a dangerous level of foreign dependence in about five years. [Ref. 9:p. 21]

To most within the DOD and the federal government, "the concept of 'dependence' on overseas suppliers for critical military inputs [is] foreign indeed." [Ref. 25:p. 100] The U.S. has no past experience with being dependent on foreign technology which is critical to its defense. The market power of a single foreign source supplying critical items could be enormous and might result in higher defense systems cost if only one firm supplied the items or if the country formed a cartel to fix export prices. The implications for transfer of classified information or the potential for non-acceptance of classified material is also very disconcerting. [Ref. 9:p. 20]

The semiconductor industry is not comprised only of DRAMs, however. Today, America's primary strength is in innovation. Microprocessors, the second largest selling chips, are much more profitable than DRAMs. Their market is dominated by the American firms of Intel and Motorola as much as the Japanese dominate DRAMs. Many, however, maintain that DRAMs are a 'technology driver' and their domestic supply is vital to a flourishing electronics industry in the future. [Ref. 26:p. 66]

Even for DRAMs, IBM is the largest producer, but because it consumes all it produces, its output is not included in market-share figures. [Ref. 27:p. 16] Because firms such as IBM and AT&T consume all the semiconductors they produce, they are termed captive producers. Comparisons of DRAM producers only consider merchant producers, those who sell their semiconductor chips on the open market. If IBM and AT&T could supply the U.S. with the right type of advanced semiconductor chips in the event of a military crisis, foreign dependence might not be such a risky proposition.

Why is it really that bad to become dependent on foreign firms? The alternative to maintaining a secure domestic semiconductor industry is to use devices manufactured by foreign firms or manufactured in the U.S. under foreign license. This option, however, may reduce the flexibility of U.S. foreign policy or compromise the advantage in U.S. military technology. [Ref. 3:p. xvii] Of course, foreign countries such as Japan may be unwilling or unable to restrict exports to the U.S. because of their dependence on the U.S.

As the potential for cost savings increases with multiple foreign sources of defense system components, brought on by increased 'globalization' of manufacturing technologies in semiconductors, as well as many other products, the trade off with the associated security risk must be considered very carefully. [Ref. 25:p. 105]

2. How Long Will the Next War Last?

At the conclusion of World War II, only the United States possessed an atomic capability. Shortly thereafter, the Soviet Union developed atomic power. For the next few years, as additional R&D yielded weapons with greater and greater destructive power, the U.S. and the Soviet Union began a standoff policy of deterrence. Many felt that conventional warfare had come to a close forever. The years since then have proven those theorists wrong as literally hundreds of conventional battles and wars have been fought with no escalation to a nuclear exchange. According to a 1960 RAND Corporation study entitled, "The Economics of Defense in the Nuclear Age," extensive economic planning for an extended war has become irrelevant now that we have entered the nuclear age. The authors argued that preparation for a sustained conventional war should take the lowest priority for U.S. preparations because of its unlikeliness. [Ref. 28:pp. 13-4] Throughout the years since the nuclear age began, the U.S. has come to depend upon the nuclear umbrella for protection. Conventional warfare equipment has taken second place to strategic nuclear weapons. In the past few years, numerous authors have written that a nuclear war is becoming less and less of a threat, but that conventional warfare has replaced it as a means of power projection. Although the U.S. has the recognized technological superiority, the size of its conventional arsenal casts doubts toward its ability to wage an extended, conventional war with the Soviets.

Although the U.S. has recommited itself to conventional deterrence, it continues to develop only limited numbers of expensive high-tech weapons. A paradox exists because conventional wars are historically wars of attrition. If the U.S. were to become involved in a conventional war, despite its sophisticated weapons, it would still only be able to sustain war for a limited time. [Ref. 25:p. 104]

Some ask if the U.S. industrial base were to continue to shrink and a large scale conventional war developed, could American production capacity still support a war of attrition? Others ask if the potential adversaries of the U.S. in a large scale conventional war could support a war of attrition themselves?

Some suggest that if the U.S. were to become involved in a coalition war where foreign supplies of semiconductors were no longer available and its domestic capabilities had declined, the most critical constraint placed upon any necessary wartime production surge might be the number of skilled craftsmen left in the U.S. [Ref. 18:p. 32] Today, due to the complexity of the most advanced microchips, most production is accomplished by machines and robot devices. Engineering expertise would still be required to design and build high-tech production equipment.

Would it be necessary to maintain a production capability for semiconductors if we expected a nuclear war? The U.S. capacity for long term military production would probably count for very little when compared to its capacity for first strike and retaliation if a nuclear war began.

In a conventional war, would a submarine campaign be a major factor in disrupting U.S. sea lines of communication and international trade conducted on the high seas? In a limited war, such as the conflicts in Korea or Vietnam, is there much probably of a Soviet submarine campaign directed towards international trade among U.S. trading partners? If not, why should the U.S. protect its semiconductor industry at all? Could the U.S. continue to import its supplies from throughout the world? These questions are not easy to answer, in fact, they are impossible to answer short of knowing the future. The U.S. then, would be wise to choose either a worst case or a most probable scenario and base decisions on the corresponding expected costs and benefits. [Ref. 23:pp. 149-50]

C. THE ECONOMIC THREAT

Some feel that in order to continue to produce the technology to meet the needs of an increasingly more sophisticated military, the U.S. will need to maintain a healthy, internationally competitive semiconductor and electronics industry and safeguard its technological superiority. If the U.S. cannot compete successfully, its world markets would shrink, causing an erosion of the industrial base which has become so heavily dependent upon electronics. They warn that if no short term policies are enacted to minimize a relative decline in the U.S. semiconductor market for DRAMs, the U.S. could become increasingly dependent upon foreign technologies for its defense, while its economy weakens. [Ref. 22:p. 139]

Economic strength goes hand in hand with military strength. As Schlesinger argued, "the efficient use of economic capabilities could provide the critical margin needed for victory." [Ref. 25:p. 100]

One perception widely held by our major competitors is that leadership in the semiconductor industry can result in leadership in many industries. [Ref. 15:p. 7] Conversely, many believe the U.S. may experience a loss of its leadership in the semiconductor industry, possibly resulting in a loss of leadership in many industries. The cost of losing the technology edge to foreign companies would certainly be high in many respects, "but to lose out in the competition in future technologies, if that indeed should occur, would be even more disastrous." [Ref. 18:p. 29]

If the U.S. is to regain the technological lead which many believe has already largely been lost to foreign competitors, proponents of federal intervention maintain that it must act quickly and decisively. Some feel that "because technological knowledge is cumulative, once technological leadership is lost, it is very difficult to regain. The United States, therefore, has an ever-shortening window of opportunity in which to regain technological leadership before it finds itself behind the state-of-the-art." [Ref. 15:p. 10] Others, however, recognize that it was possible for nations such as Japan to make amazing strides forward even when the U.S. was the leader in technology and production techniques.

The Japanese position in the semiconductor industry today did not come without a cost. For the first few years, they lost some $4 billion as they targeted a high volume manufacturing capability for DRAMs, but over expanded their capacity. Today, due to a U.S.-Japan trade agreement which effectively increased their market power, Japanese manufacturers are making huge profits which frees more capital investment in R&D aimed at closing the U.S. lead in state-of-the-art semiconductor technology. The chip agreement has enabled the Japanese to become "much more formidable long-term competitors." [Ref. 11:p. 81]

Finally, it is important to note that much of the thrust behind the current call for government involvement in the semiconductor industry has relied upon the national security issue. However, DOD has very little leverage with the commercial semiconductor industry, because only three percent of the its output quantity is acquired by the military. [Ref. 9:p. 6] Thus, spill overs from defense programs to the general economy are likely to be somewhat limited, particularly with regard to DRAM production.

D. DO CONDITIONS IN THE SEMICONDUCTOR INDUSTRY POSE A NATIONAL SECURITY THREAT?

Earlier in this chapter, the positions of those who believe in the necessity to maintain a domestic production capability for semiconductors in case of war was discussed. There are others who seriously question the rationale for that conclusion. They recognize that although the U.S. has lost the lead in DRAM manufacturing technology and is continuing to lose market share in other areas as well, such as microprocessors and EPROMs, innovation is still strong in the U.S. They question whether the cost of R&D to maintain the technological lead is worth the expense since imitation through reverse engineering is so much less expensive than performing leading edge R&D.

1. Military Threat

What weapons rely on semiconductors? Today, virtually all weapons and weapons support systems, except the most simple, somehow incorporate semiconductors. Earlier in this chapter, a number of weapons systems were listed which depend entirely on semiconductors produced outside of the U.S. As weapons technology becomes more sophisticated, the use of advanced semiconductors becomes more and more common. Weapons that now depend on semiconductors range from strategic nuclear deterrence weapons to tactical communications systems.

If strategic nuclear weapons are ever used, there would seem to be no further need for resupply of damaged semiconductors because of the expected severity of damage. In a conventional conflict, however, resupply of vital communications equipment would be essential to ensure proper command and control for weapons systems employed. Especially in low intensity conflicts around the world, semiconductor resupply would be critical to sustaining the fight leading to a victorious conclusion.

What scenarios are most likely? It would appear that in light of recent world events involving the apparent decline of communism that large scale war is not very likely. Low intensity conflicts, civil unrest, and wars of proxy are the most likely scenarios for which the U.S. must plan. In that type of conflict, if the U.S. became dependent on foreign supply of semiconductor chips, the chance of a cutoff of those supplies would be small. Another possibility exists, however, where the foreign supplier may decide to cut off U.S. semiconductor supply if they disagreed with U.S. foreign policy. Of course, this threat is diminished to the extent that foreign dependence on the U.S. limits their ability to cut off supplies. Furthermore, IBM , AT&T, and other captive U.S. producers could provide the necessary semiconductor chips during a national security emergency.

If the U.S. captive industry is insufficient or inappropriate, another possible solution to this potential problem might be to maintain a diversified portfolio of foreign suppliers to provide insurance against having all semiconductor supplies cutoff. Instead of depending on only Japan for its semiconductor needs, the U.S. may opt to contract with other Pacific Rim nations and European nations to provide semiconductor chips. Similarly, a strategy of encouraging foreign owned corporations to produce semiconductors in the U.S. could be effective. Another option might be to encourage U.S. firms to engage in joint ventures with foreign firms in order to share advanced technologies and benefit both nations concerned.

These options would enable the U.S. to be virtually assured of required semiconductors supplies in case of war and take advantage of lower costs from foreign suppliers. Furthermore, these options would eliminate the requirement to pour billions of dollars into R&D for semiconductor manufacturing technology, where Japan already has the world lead, and use the money instead to satisfy other defense or civilian needs.

2. Economic Threat

Because national security includes military and electronics dimensions, it is important to consider how critical DRAMs are to the electronics industry and to the U.S. economy. Those who promote a domestic DRAM capability argue that DRAMs are technology drivers. In other words, advanced capabilities in DRAM technology allow other semiconductor technologies to advance. There are others that argue that DRAM manufacturing technology is at the low end of the technology spectrum and despite the exodus of mass DRAM manufacturing capabilities offshore, the U. S. still enjoys the lead at the high end of the spectrum in innovative and custom use semiconductor chips.

Do we need to maintain the lead in basic areas to maintain the lead in advanced areas? The DRAM market industry lead has shifted from the U.S. to Japan over past few years, but the U.S. continues to be the technology leader through numerous small semiconductor companies that thrive on innovation and customized microchips. While the future may bring about a shift in this situation, no decline in the U.S. technology lead has yet been observed.

Why does technological superiority have to come from the U.S.? For many years, the U.S. has been the technology leader in electronics and most recently in semiconductors. Despite this fact, the Japanese have achieved remarkable success by importing U.S. technology, improving upon it, adding various enhancements to consumer products, and selling them back to the U.S. consumer at very competitive prices. The main reason for this situation is that R&D costs are very high and increasing for each successive generation of innovation. For the past 20 to 30 years, the U.S. has paid the R&D price, while the Japanese and others have been patient to wait and imitate U.S. innovation. The lower cost of capital in Japan has also enable Japanese companies charge lower prices for their semiconductor products.

In order to maintain U.S. national security, the U.S. then must have access to advanced technology, but not necessarily sole possession of that technology. Since the Soviet Union has such overwhelming numerical superiority in military forces, however, they must be denied the most advanced technologies available in order for the U.S. to maintain a military balance vis a vis the Soviet Union.

Conflicting opinions make a definite conclusion of whether or not national security is significant justification for federal intervention impossible. For the sake of argument, however, the next chapter of this thesis will adopt the premise that the national security issue requires a domestic source of semiconductors to provide a stable supply of chips in wartime and to maintain the U.S. technology lead. Given that federal policy makers appear to have accepted this premise, the following chapter will examine alternative policies to ensure a domestic source of semiconductors. Given that a domestic production capability is not necessary to maintain U.S. national security, an alternate approach will be addressed in the final chapter.

IV. FUTURE OPTIONS FOR THE U.S. GOVERNMENT

Because U.S. national security depends on both an adequate supply of semiconductor chips, both for now and for the future, and on the capability to design advanced semiconductor products for use in superior weapons systems, many assume that a domestic semiconductor manufacturing capability and R&D sufficient to stay in the technological lead are necessary. Unfortunately, the external benefit of national security derived from leading edge technology is not considered by private sector firms interested in profit maximization. This market failure can be categorized as an appropriability imperfection.

There are several reasons for the U.S. semiconductor industry's alleged decline relative to Japan. Today's extremely high cost of R&D means that larger and larger amounts of capital are necessary to finance each new generation of semiconductor chips. The Japanese currently have an advantage in this area because interest rates in Japan have been lower than interest rates in the U.S. In the late1980s, however, interest rates have been getting closer and closer as capital markets have become more international.

More liberal anti-trust laws and government encouragement have allowed Japanese semiconductor firms to become much more vertically integrated than their U.S. counterparts. This industry structure allows Japanese firms to more readily take advantage of economies of scale, cross-subsidize certain products within their corporations, and absorb short term fluctuations in production levels. During the infancy of the semiconductor industry in Japan, the Japanese government granted subsidies to stimulate production and to protect its new domestic industries.

For these reasons, among others, the Japanese semiconductor industry today enjoys a competitive advantage over the U.S. semiconductor industry. As more and more of the world semiconductor market shifts to the Japanese, additional profits are being reinvested in R&D projects to ensure their future growth.

Advantages for Japanese business are not limited to just the semiconductor industry or to the electronics industry. Although the semiconductor and electronics industries are very important to both the U.S. and Japan, they still comprise only part of their respective economies. Merchant semiconductor manufacturers in the U.S. have been accused of prematurely resorting to the national security justification for increased government support for their struggling businesses. If the real problem for the semiconductor industry is indirect failures of the U.S. economy caused by macro factors such as the higher interest rates and more stringent anti-trust laws in the U.S., then federal intervention on a micro level would not be justified.

Most economists would agree that free international trade is the best option for the world economy as a whole, because of its inherent efficiency. Individual groups may lose, however, if free trade is practiced since free international trade favors no particular individual groups. Protectionist policies tend to favor specific industries, but hurt the overall economy. As more obstacles to free trade are instituted, a nation's economy becomes less and less efficient. Although the overall economy loses, the government of that nation may gain from income derived from tariffs and customs duties when protectionist policies are instituted. [Ref. 29:p. 6]

Scarce federal dollars for appropriation to various governmental programs is an increasingly important political issue. Are the public benefits which may be derived from federal spending in the semiconductor industry worth the resulting increase in the federal deficit? Many believe the answer is yes. Some argue that the national security benefits coupled with the economic benefits that would be reaped from the success of the U.S. semiconductor industry in related industries would be well worth the cost and even vital to the survival of the U.S. economy. [Ref. 3:p. 37] Others argue that federal government action to encourage R&D is necessary for the U.S. semiconductor industry because "the market, left to its own devices, will not invest in the 'right' amount of R&D and will not make these investments in the 'right' places." [Ref. 3:p. 30]

On the other hand, some analysts believe that national security benefit it is small and that economic benefits should encourage private investment in R&D. Furthermore, the federal government is not effective at identifying the "right" amount of R&D and the "right" places. Therefore, federal intervention is not justified according to this view point.

Assuming that federal intervention is justified on a national security basis, a number of options available for the federal government will be discussed in the following sections. These options include a hands off policy, tariffs, strategic stockpiling, Buy American regulations, DOD production, anti-dumping measures, subsidies, and industry consortia.

A. HANDS OFF POLICY

As discussed earlier, the free trade which would result from a hands off policy by all trading nations, would be the most efficient policy and bring the most benefit to world trade as a whole. However, this may not be the best solution for each individual trading nation or each industry in that nation.

One reason to support a hands off policy for the U.S. federal government might be the historical lack of past success of federal interventions. As in the case of anti-dumping measures taken in 1985, which lead to the U.S.-Japan Semiconductor Pact of 1986, the U.S. government's solution was actually counterproductive and probably resulted in more damage than protection for the semiconductor and electronics industries.

The Bush Administration has not taken any specific action to encourage improvements in the semiconductor industry because of its desire not to single out any particular industry for support which may result in negative fallout for other industries. Their lack of action policy thus far has effectively been a hands off policy. This hands off policy has resulted in a number of U.S. semiconductor firms negotiating joint ventures with foreign firms to share advanced semiconductor technology, especially in DRAM manufacturing. Texas Instruments has teamed with Hitachi, Intel with NMB, and IBM with Siemens. Perhaps this trend is only a means for survival. There has also been a number of industry consortia formed to offset rising R&D costs for future semiconductor technolog.es. Some have had limited success, while one, US Memories, recently gave up before it even started, due to lack of financial support from its potential members.

Some feel that "the market for semiconductor chips is working well, if only politicians will leave it alone." [Ref. 27:p. 17] They feel the Department of Defense should also leave the industry alone as, "already the Defense Department's export restrictions, designed to keep high technology out of the Soviets' hands, allow Japanese firms to capture foreign markets that otherwise would be American." [Ref. 13:p. 11]

A hands off policy would definitely be the option with the lowest appropriations cost, but the results could potentially be very costly to the nation as a whole if it failed to protect national security.

There are a number of shortfalls associated with joint cooperative ventures with foreign firms. First, to the extent production of semiconductor products in these cooperative ventures is concentrated overseas, they do very little to guarantee a secure supply of semiconductors for the U.S. Second, it is important to consider the type of technology that is transferred in each direction, to determine the potential impact on national security. Similarly, patent and licensing agreements are difficult to enforce with foreign firms which sometimes leads to the escape of vital high technology secrets such as with Toshiba selling computer products to the Soviets. Finally, the potential exists for a nation such as Japan to deny the exportation of advanced technology products if they are to be used ultimately in weapons systems.

If a hands off policy were to be adopted by the U.S., a short term fallback position to ensure an adequate supply of advanced semiconductor products in a crisis situation might be to depend on captive semiconductor producers such as IBM and AT&T which consume all the chips they produce.

B. TARIFFS

Tariffs are duties imposed on imported goods. If a nation's government wishes to protect a new industry from foreign competition, a simple tariff might seem reasonable. Tariffs tend to create an adversarial relationship between trading nations and encourage retaliatory behavior. Prior to the General Agreement on Tariffs and Trade, the use of tariffs was excessive. In recent years, this volatile political method has been avoided for the most part through international agreements. Various other means of protectionism have been used which do not envoke the same emotion and tendency toward global tariff wars. [Ref. 30:p. 14] A number of these non-tariff methods will be discussed later in this chapter.

The use of tariffs also tends to address the symptoms of a problem, rather than the causes of a problem. In the semiconductor industry, the national security problem is the lack of domestic production capability. The cause of the problem is high interest rates and excessive anti-trust regulation. Tariffs are not likely to be successful in the long run because they address the symptoms, not the causes of the problem. Today, tariffs, as a means to protect domestic industries, are very much discouraged. [Ref. 30:p. 22]

While tariffs may appear to be a simple solution for certain market imperfections, politicians who support them "fail to address the charge that whenever industry and agriculture are protected, they become less productive." [Ref. 18:p. 33] Furthermore, tariffs are hard to remove once they are in place.

C. ANTI-DUMPING MEASURES

The effects of anti-dumping measures are very similar to those of tariffs. Anti-dumping measures address only the symptoms of a market failure, create forces for retaliatory actions by opposing nations, and historically have not been effective in solving trade problems.

For several reasons already discussed, Japanese semiconductor manufacturers have been able to sell their products at lower prices than can U.S. manufacturers. In the past, U.S. semiconductor firms have accused the Japanese of dumping their DRAM chips on the U.S. market.

> According to Article VII of GATT, dumping is defined as the sale of a product abroad at a lower price than is charged domestically. If that price difference is judged to cause material injury to an established domestic industry, that country may impose an antidumping duty to bring the price in the domestic market up to the price in the market of the exporting country. [Ref. 29:p. 70]

However, some argue that Article VII of GATT "overly favor[s] domestic producers at the expense of domestic consumers." They argue that the lower prices charged in a foreign market may merely reflect a rational for profit maximization through international price discrimination, rather than predatory dumping. They say that predatory dumping in the U.S. is much less of a problem than semiconductor industry spokesmen allege and merely a convenient excuse for further government protection. [Ref. 29:p. 70]

Despite doubts about the intent of alleged dumping, past anti-dumping measures have produced questionable results. "For example, import quotas for DRAMs, negotiated with the Japanese in 1986, had significant adverse effects on the computer and electronics industries, but did not seem to help the U.S. DRAM industry." [Ref. 31:p. 552] Some feel that the fallout from this agreement caused "a severe shortage of memory chips, brought on at least in part by well-intentioned, but misguided trade policy from Washington." [Ref. 11:p. 79] If the U.S.-Japan Semiconductor Agreement of 1986 had not been negotiated, market forces may have encouraged

> Japanese chipmakers . . . [to expand] . . . production to meet demand. But instead, between August 1986 and August 1987, while demand rose some 30%, MITI administered a 32% reduction in the output of the 256K D-RAM, the then dominant memory chip. Japanese firms cut back investment and shifted efforts from current-generation chips to the next generation. [Ref. 11:p. 81]

If recent history has a lesson to tell, it may be that anti-dumping measures may cause more problems than they solve. Anti-dumping policies tend to single out a particular product or sector, rather than taking a big picture view of an industry or the national economy. Again, anti-dumping policies are short-term attempts to solve a long-term problem. Future consideration of anti-dumping measures should include an in depth review of its effects on related industries prior to implementation.

D. STRATEGIC STOCKPILING

One method suggested to alleviate the increasing dependence on foreign sources of semiconductor products by the U.S. is through strategic stockpiling. The U.S. already stockpiles strategic raw materials which its political and military leaders feel would be essential to the execution of a large scale military conflict. Some proponents of this method feel that,

> Stockpiling foreign-made semiconductors may be one feasible answer to the unlikely threat of interrupted supplies. Should the use of foreign military components or demand for foreign military components or demand for foreign goods seem to present a legitimate cause for worry, domestic manufacturers could be designated as back-up suppliers in case of a national emergency or mobilization. [Ref. 7:p. 52]

In a method such as this, many questions arise. If a stockpiling policy is adopted, what level of supply would be required to insure an uninterrupted supply of semiconductors? Would the advancement of technology in the semiconductor field make stockpiles obsolete quickly? What cost would a stockpiling policy entail for the federal government and for the Department of Defense?

As discussed in an earlier chapter, determination of the length of the next war can only be based on speculation, hence, the required level of semiconductors stockpiles can only be speculation. As advances in semiconductor products are made, leading edge technology will most likely make stockpiled semiconductor products obsolete in a number of years, if not months. The U.S. strategy to maintain the technology lead to counter its potential adversaries' numerical superiority would be at risk if it depended on foreign suppliers to deliver state-of-the-art microchips. The cost of renewing a stockpiled supply of semiconductors to prevent obsolescence, coupled with the initial investment in stockpiles aimed at satisfying the need for a conflict of reasonable duration appears to be quite excessive. Stockpiling makes no attempt to solve the problem of maintaining the capability to exploit new developments in semiconductors through increased R&D, but only attempts to solve the short-term problem of an assured supply of semiconductor chips.

> For the first time in its modern history, the United States is likely to have a defense industry which relies on foreign suppliers for items ranging from armor plating to ceramics to semiconductors. As dependence rises, pressure will inevitably be placed on the Defense Department to expand the size and scope of its stockpiles. Stockpiling, in turn, will draw resources from other budgetary items. [Ref. 25:p. 105]

Economically, this method makes no attempt to solve the market imperfection caused by the lack of concern for the public external benefits of national security derived through advanced domestic production, but merely attempts to apply a bandage at a significant, reoccurring cost to the federal government.

E. DOD PRODUCTION

Another option available to the federal government to insure a supply of semiconductors for national security reasons would be through DOD itself building manufacturing plants to produce semiconductors solely for defense needs. The effects of this type of policy are very similar to those of strategic stockpiling. DOD production also addresses the supply problem at the exclusion of the R&D problem. One advantage to this method is that it would give the federal government a high level of control for the production of semiconductors.

On the other hand, there are a number of disadvantages including cost overruns and lack of advanced technology expertise. For example, a related government project, the Very High Speed Integrated Circuit (VHSIC) program, "originally was planned to cost $200 million over 10 years. The VHSIC budget has expanded to approximately $1 billion in order to incorporate the technology into military systems." [Ref. 7:pp. 51-2]

Government production could guarantee a secure supply of required semiconductor chips capable of current technology at the time of plant construction, but could not guarantee that the production would keep up with advancing technology. Government production may be more appropriate for industries and products which involve stable technologies.

DOD production focuses exclusively on the Defense Department's requirements for advanced technology weapon systems, while ignoring the semiconductor industry as a whole. Economically, this option is flawed because it encourages large government expenditures which only benefit the military aspect of national security. This method of federal intervention fails to address the problem of an alleged loss of advanced technology in the U.S., but only DOD's demand for semiconductors. At best, DOD production would again function as a bandage, when a major operation is required.

F. BUY AMERICAN POLICY

One means of restricting the purchase of foreign goods is through Buy American restrictions. The Congress has enacted legislation which requires federal agencies to only purchase products produced domestically even if they cost up to 50% more. [Ref. 23:p. 7] Currently, North Atlantic Treaty Organization (NATO) member countries are exempt from this policy, while Japanese products are still discriminated against.

Unfortunately, even if the federal government did not exempt NATO nations, their market power to make an impact on the world semiconductor market would remain quite small. When Buy American rules were instituted during the great depression of the 1930s, they could make an impact. When DOD was the primary consumer for the semiconductor industry, Buy American rules had a significant impact on foreign competition. Since DOD today only accounts for roughly three percent of the demand for merchant DRAM production output, Buy American rules are not likely to play a significant role in reviving the U.S. DRAM semiconductor industry. Buy American restrictions, today, essentially only raise the level of government expenditures. Even with a Buy American policy in place,

> until recently, the Pentagon seemed unconcerned with the national-security implications of foreign-produced electronics. To save costs or reward allies, the Department of Defense (DOD) last year [1986] awarded more than $9 billion in contracts to foreign firms--about 6 percent of total procurement. [Ref. 7:p. 47]

This policy makes no attempt to solve causes of the problem, but addresses only the symptoms. The prospect for Buy American restrictions encouraging any meaningful improvement in the semiconductor industry is grim.

G. SUBSIDIZED DOMESTIC PRODUCTION

In order for the government to protect one of its industries from foreign competition, subsidies may be employed either to maintain the preeminence of a domestic industry over foreign competition or simply to level the competitive playing field that may be in favor of a competitive foreign industry.

Economists tend to favor this form of federal intervention because it treats the market failure, rather than merely applying a bandage to the symptoms of the market failure. Because the commercial semiconductor market does not recognize the external benefits of national security derived from maintaining a lead in advanced semiconductor technology, subsidies would tend to encourage the semiconductor industry to produce those products which are subsidized.

In the semiconductor industry, for example, some have recommended that government subsidies be granted to domestic producers of DRAM semiconductors to counter the growing U.S. dependence on foreign sources for state-of-the-art semiconductors. DRAMs, however, are not state-of-the-art technology. Even if they were, vertically integrated computer companies in the U.S., such as IBM and AT&T, would be capable of supplying the Defense Department with the DRAMs necessary in a military crisis. [Ref. 13:p. 11]

The Defense Department's demand for microchips today is primarily for customized chips which have few commercial applications. Subsidies designed to offset the asymmetrical costs of foreign competitors and aimed at the DRAM market would do little to stimulate the market for high-performance semiconductors required for national security considerations. To summarize,

> From a commercial point of view, DOD could better strengthen the industry by helping consolidate the U.S. lead in low-volume, high-performance products. This approach would also make sense militarily since weapons and other DOD applications generally require custom designs produced in low volumes. [Ref. 7:p. 50]

Subsidies for semiconductor products do address the external benefit of national security. However, to be most effective, they should target those products most important to DOD. In order to target a specific product or industry, general subsidies are not required nor desired. Specific subsidies aimed at DRAMs for example, would have the same limited effect as Buy American restrictions, because of the relatively small size of DOD's demand, and have the same drawbacks for their employment.

H. CONSORTIA

The formation of consortia is one method used for market correction which has become increasingly popular in recent years. Consortia are organizations of firms with common interests which pool their resources to provide advantages to their member firms. Their popularity in the U.S., of late, reflects their apparent success in Japan.

Historically, "because U.S. firms have acted independently, each company is burdened with the full costs of advancing every aspect of new technologies. In an era of rapidly increasing costs of technology development, independent and duplicated efforts hinder competitiveness." [Ref. 15:p. 2] Unfortunately, "the concept of a consortium is still an alien idea here." [Ref. 32:p. f-15]

> The Japanese have effectively used consensus and negotiation as a methodology for solving technical problems. In contrast, American industry has often been built on adversarial and contractual relationships. [Ref. 15:p. 18]

> In the past, U.S. semiconductor firms have not supported cooperative research in the early phases of process and materials development. This adversarial atmosphere created inefficiency, redundancy, and even the misapplication of equipment, and it limited the financial resources applied to any single effort to those that could be borne by a single firm. [Ref. 15:p. 20]

Another drawback is the tendency among U.S. firms which participate in consortia to hold back their most competent and promising researchers and ideas out of concern for the potential benefits their competitors may derive. [Ref. 33:p. 11] This is particularly true for consortia involving markets where some firms have significant, independent research activities while others have little or no independent research. The members who have significant independent investments are reluctant to join for fear that their competitors will benefit from their independent efforts.

For years, the formation of consortia was prohibited in the U.S. because their formation violated various anti-trust laws. Recently, the federal government has begun to loosen certain anti-trust laws. Examples of semiconductor consortia that have been formed are the Microelectronics and Computer Technology Corporation (MCC) and the Semiconductor Manufacturing Technology (Sematech). MCC was formed completely as a private sector endeavor. Sematech, however, is funded cooperatively with the government. A more recent attempt to form a consortium, US Memories, failed even before it was established because of a lack of financial commitment from its prospective members.

While some proponents of semiconductor industry consortia believe that a one third cost savings is possible for microelectronic technology firms which participate in R&D consortia, there are many that oppose the consortia concept. [Ref. 34:p. 20] Many who oppose the formation of consortia feel that because the semiconductor industry was built by brazen entrepreneurs, the same approach should continue. They cite problems with attracting the best researchers and the best ideas. There is speculation that even among consortia members, one motivation for joining the consortium lies in hedging their bets in case any new breakthrough technologies are developed.

The success of consortia in the U.S. has yet to be determined. While there are many reasons why the concept may not work, there is also potential for its success. Using government support for consortia, such as Sematech, is justified if the external benefits derived from its success are sufficient to offset the costs. This option is capable of stimulating R&D in the semiconductor industry if it could be employed properly, but it is unclear at present whether either Sematech or MCC have developed the proper framework. Consortia addresses at least one of the problems of the semiconductor industry, inefficient market structure, rather than just the symptoms.

I. SUMMARY

The options discussed in this chapter, which target specific sectors such as the semiconductor industry, have had varying degrees of success. All have been employed in numerous cases with a wide range of results. A micro approach might be used to attempt to solve the semiconductor industry's problem, but serious consideration must be given to macro policies which tend to stimulate the economy as a whole.

The concluding chapter will include possible macro government economic policies designed to stimulate the entire economy rather than targeting specific industries as do the options discussed in this chapter.

V. CONCLUSION

As discussed in the previous chapter, several options are available to the federal government to stimulate the semiconductor industry. Although the U.S. semiconductor industry appears to suffer from competitive disadvantages when compared to the Japanese semiconductor industry, these disadvantages appear to affect the economy as a whole, not just the semiconductor industry. While micro solutions may have a positive effect on a single industry such as the U.S. semiconductor industry, the potential for detrimental effects on related industries is a very real possibility, like the results from the U.S.-Japan semiconductor pact of 1986. Furthermore, some micro solutions may evoke retaliatory responses from our trading partners. Since the lack of competitiveness for the U.S. semiconductor industry appears to have been caused by macro effects on the economy, it would seem reasonable that a more practical, long-term solution involving macro policies would better solve the semiconductor industry's problems. These policies would address the actual causes of the current problems and affect the economy as a whole, rather than just one specific part. Thus, these policies would address both the military and economic dimensions of the national security issue.

Earlier in this thesis, the reasons for Japan's competitive edge in business were discussed. Some of those reasons include the lower cost of capital, protectionism policies, industry structure, educational system effectiveness, and cultural biases.

A number of macro policies are available to stimulate this overall economy. While a complete discussion of these policy options fall outside the scope of this thesis, a brief discussion is included.

The cost of capital in the U.S. could be reduced debt if were discouraged and savings encouraged. For example, if the federal deficit were reduced or eliminated, it would significantly reduce the demand for capital and interest rates. Conversely, the supply of capital could be increased by encouraging personal savings through changing tax laws to increase deductions for Individual Retirement Accounts and eliminating double taxation of personal savings accounts. Finally, capital investment could be further encouraged by reinstituting investment tax credits for business investment and by reducing capital gains taxes.

The U.S. industry structure could be allowed to become more vertically integrated to more readily compete with the large Japanese conglomerates and Japanese consortia by relaxing anti-trust laws. At present, IBM and AT&T are restricted from entering the merchant DRAM markets because of such laws.

Scholarship programs could be offered to stimulate interest in scientific and engineering disciplines at all levels of education to recover the lead so important to the U.S. technological superiority of the last few decades.

While the Japanese have been very successful with their business approach, differences in Eastern and Western culture prevent the Japanese business culture from being as successful when applied to American business as it is in Oriental cultures. Adopting certain Japanese style business approaches which would complement the American business culture, rather than just copying the Japanese because they have been successful, could pay big dividends in international business and trade.

A RECOMMENDATIONS FOR FEDERAL INTERVENTION IN THE SEMICONDUCTOR INDUSTRY

Since the U.S. has come to depend on high-tech components for its weapons systems to counter the threat of its numerically superior potential adversaries, a reliable supply of semiconductor products is vital to the military aspect of its national security. While macro policies appear to be the best approach to solving this problem, they will take time to be enacted and to take effect. Problems such as the high cost of investment capital in the U.S. and the decline in the U.S. educational system cannot be solved in the short-term.

At this critical crossroads, the U.S. cannot afford to wait until long-term policies take effect because the lack of a reliable source of the most advanced semiconductor products for weapons systems could open a window of vulnerability for its national security. To conclude the research and analysis of this thesis, two areas of recommendations are offered. First, short-term recommendations are made to minimize the U.S. window of vulnerability. Second, long-term recommendations to solve the macro problems of foreign competitiveness are made.

For the short-term, it is recommended that the U.S. government institute a policy where the DOD would contract with a large number of foreign suppliers in order to obtain the most advanced technology and to minimize the risk of interruption of supplies. The chance of an interruption of critical supplies in time of national or military crisis would be minimized by employing widely diversified sources of supply. This policy would also tend to be the most cost effective because the current cost of capital for U.S. based R&D and capital investment would make fostering a domestic DRAM industry expensive. These funds could probably be used more effectively elsewhere.

For the long-term, it is recommended that the U.S. government employ a number of macro policies to stimulate an improved competitive environment for American business. First, fiscal responsibility in the federal budget process should receive a much higher priority in order to eliminate the federal deficit and reduce the federal debt. This will serve to reduce interest rates making investment in R&D and other areas much more affordable for American business.

Second, in order to encourage more business investment, the federal government should consider reinstituting the investment tax credit. This would serve to attract more investment funds and make American business more competitive with foreign firms.

In order to compete with large, vertically integrated firms such as those in Japan, a national policy to loosen anti-trust laws is recommended. Since many merchant semiconductor chip producers in the U.S. are so restricted in their markets, short-term fluctuations in market demand are often devastating to their profitability. By allowing companies to vertically integrate, the different segments of their business can absorb market fluctuations more readily. Considering the level of international competition, relaxing anti-trust laws is unlikely to lead to excessive market power in U.S. markets.

It is recommended that a national policy of increased emphasis on education be instituted to help bring the U.S. back to preeminence in the science and engineering fields. While U.S. colleges are still at the forefront of worldwide education, the quality of primary and secondary education, to prepare students for college, has declined in recent years. Many foreign students are filling a void in U.S. college classrooms in the science and engineering fields because American students either are not qualified to attend or because they have no desire to attain a technical education. "While our educational system has concentrated on educating talented students in theoretical disciplines, it has neglected training for manufacturing. In addition, manufacturing industries have been slow to communicate their needs to institutions of higher education." [Ref. 15:p. 17] Perhaps scholarship programs to stimulate more participation in technical curricula along with more government supported research at the college level would be appropriate.

An important effect of a more competitive business environment for the semiconductor industry is the improved potential for increasing the market share for consumer electronics. Improved profitability for producers of consumer products will free additional capital for future investment in advanced consumer semiconductor products which very well may have military applications to further enhance U.S. national security.

B. RECOMMENDATIONS FOR FURTHER STUDY

The limited scope of this thesis precluded the further study of a number of issues. Several areas where continued research and study may be of interest are:

- What are realistic defense scenarios for the future? How will the U.S. determine future demand for semiconductor resupply in each scenario? How do differences in the scale of the conflict (small versus large) and duration (short-term versus long-term) affect the answers?
- What are the opportunity costs of maintaining self-sufficiency in the semiconductor industry? How long can the U.S. afford these costs?
- To what extent are Japan and other foreign suppliers dependent on the U.S.? Is a cut off of critical items likely?
- To what extent does the U.S. depend on foreign suppliers of manufactured goods (specifically semiconductors and eletronics) to meet critical defense needs? Where are these imported products used?
- Is diversity of foreign suppliers for critical semiconductor technology a realistic solution to the current economic and national security problems? How much diversity (number and capacity) would be sufficient to minimize the national security risk at an acceptable cost? Should U.S. captive semiconductor producers be considered in this area of study?

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